Express Mail Label: EL618698748US 11-09-00 Case No.: 1511-00 A

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Inventor(s): Keith Luker of Patterson, New Jersey

For: EXTRUDER MIXER

Also enclosed are:

x 7 Sheets of drawings

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Art Unit	:	36th Floor
Examiner	:	1600 Market Street
Serial No.	:	Philadelphia, PA 19103
Filed	: Herewith	
Inventor	: Keith Luker	Docket: 1511-00
Title	: EXTRUDER MIXER	
		Dated: November 8, 2000

Box Patent Applications
Assistant Commissioner for Patents
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37 C.F.R. §1.10

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Date of Deposit: November 8, 2000

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EXTRUDER MIXER

This invention relates to a new extruder mixer and method for mixing plastic or plastifiable materials, utilizing novel effects of elongational stress in the feed material, with improved mixing performance dramatically at all concentrations for the plastic mixture. The invention relates particularly to laboratory-scale mixers, and to their use in designing, building and operating full-scale production mixers using the novel concepts of this invention.

Laboratory extrusion machine builders have traditionally scaled down what the large extruder mixers have available in production. Nevertheless, when these large mixer designs are used in small extruders, they unfortunately do not compound very well.

Laboratory single screw compounders suffer from problems associated with being small. Lower shear rates, lower backflow, and the repercussions of using the same size pellets in laboratory extruders as in large extruders, all reduce the mixing compounder performance of small laboratory mixers.

Shear rates for a 5/8 inch extruder, for example, are roughly one-third that of a 4.5 inch extruder. Many workers regard higher shear rates as important to mixing. Small screws can generate much higher pressures than large extruders because of their small channel depths. Therefore, there is little back-mixing even at high pressure generation. It is a truism that, the better mixed the material enters the extruder, the better mixed is the output. Considering a simple mixture of conventional nominal 1/8 inch pellets mixed with a 1% additive concentrate of the same size and weight, one should consider how many standard 1/8 inch pellets are present at any given time in a 5/8 inch extruder compared with larger machines. For example, a 5/8 inch 24/1 L/D screw contains only 330 pellets or an average of 14 pellets per L/D. Yet a 2 inch screw contains about 905 pellets, a 3.5 about 3,600 pellets, and a 6 inch extruder about 384,000 pellets.

If we imagine a perfectly mixed 1% additive of the same pellet size, the 5/8 inch extruder will contain only 3 pellets of the additive, spread throughout 24 L/Ds of extruder length! The extruder is required to mix one pellet into 8 L/Ds of length. Even a small 2 inch extruder processes a remarkable improvement in the quality of the incoming mixture as it will have 9 additive pellets in each L/D of extruder length. Larger machines obviously have more.

The problem is worse than this, in practice, because the mixture is unlikely to be perfectly mixed. In the foregoing "3 pellet per 8 L/D" example, it is very probable that only 2 or as many as 4 pellets could be in the extruder at one time. Accordingly, there will be times when only 1 pellet might be present. If the hopper mixture were slightly uneven, there might even be a time with no additive pellets in the entire screw -- a difficult mixing problem to be sure.

This problem is so unlikely to exist in large extruders that it needs no consideration. The possible use of micro-pellets would seem to avoid these problems but such pellets are expensive, inconvenient, and often require at least one additional processing history. Accordingly, it would be highly advantageous to resolve the problem even with the use of standard or typical pelletized feed stocks.

Most single screw extruders are flood fed, by filling the hopper and the screw channel to its limit. However, compression of solids is not necessarily consistent with good mixing. In a compressive extruder where equal amounts of two types of pellets, A and B, are to be mixed in the extruder, on entering the screw, it is extremely unlikely that the mix will be perfect, i.e. A-B-A-B-A-B-A-B etc. Some inconsistent sequence will likely occur such as A-A-A-A-B-B-B-B. Compression of this sequence at high pressure often results in very sturdy "A" and "B" material where each agglomeration has to be broken up, i.e., mixed by dispersion, and then mixed intimately with each other, i.e., by distribution. This is inherently

counterproductive to good mixing.

The creation of the vertically oriented extruder improved the laboratory extruder itself, with its natural advantages of better feeding and screw strength, and dramatic increase of the L/D ratio. This is possible because the vertical screw is in tension rather than compression. This eliminates the buckling forces (caused by pressure at the tips of other screws) that otherwise destroy long small screws.

Length is an important attribute of a screw for many reasons. Length presents the opportunity to begin the melting process without compression.

BACKGROUND OF THE INVENTION

Of the many mixing elements that have been made, three fluted mixers are of particular interest. These are the mixers of G. LeRoy U.S. Patent No. 3,486,192, R.B. Gregory and L.F. Street U.S. Patent No. 3,411,179, and R.G. Dray, U.S. Patent No. 3,788,612. These mixers are often claimed to have dispersive mixing properties because the barrier clearance within the inner wall of the outer cylinder of the extruder is so small that the material is subjected to a high shear rate, the corresponding shear stress then being large enough to break down particles in the polymer melt. An important assumption in this prior art analysis is that the mixer is filled with plasticized material under compression. For example, in R.G. Dray U.S. Patent No. 3,788,612, since the material is described as plasticized and forced through increasing resistance through the mixing element, the intention of the patent is to force material, under compression, through this mixing element. The foregoing will be seen to be contrary to the substance of this invention.

SUMMARY OF THE INVENTION

In this invention the mixer is preferably an integral part of the melting zone of the screw. Therefore, the mix viscosity at the mixer is much higher than otherwise. This allows the creation of a tensile stress on the mixture, and enables novel elongational dispersion of

the mixture in the melting zone.

In order to mix at the optimum level, only a minimum amount of pressure is applied to deliver the feed material to the inlet channel of the mixer. Once the incoming plastic material enters the inlet channel, it meets one or a succession of cross-axial pumping members preferably having substantial clearance with the outer shell of the extruder, and each one takes on a cross-axial pumping function. When the cross-axial pumping, effective at an angle to the extruder axis, exceeds the inlet flow, the pumping function causes the inlet channel to become partially emptied. The plastic material that approaches each cross-axial pump is then stressed in elongation rather than compression, and remarkable mixing dispersion takes place. As the material then moves over each cross-axial pump, it is reoriented in a planar shear field. These successive reorientations take place in the absence of a worm flight as typically exists to generate pressure between two successive mixing elements. This effect may be further augmented by starve feeding of the plastic feed into the extruder, which may be controlled or assisted by screw design. Starve feeding adds a great deal of flexibility to the process and to optimization of the mixing process.

To encourage or reduce the amount of remixing, for example, additional feed rate to fill the end of the inlet channel with plastic material can be used as a control.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will further be described in detail in the drawings, which are intended to be illustrative but are not intended to define or limit the scope of the invention, which is defined in the appended claims.

Figs. 1(a) and 1(b) are views in showing a mixer in accordance with this invention.

Figs. 2(a) and 2(b) are views in side elevation showing a mixer in accordance with this invention.

Figs. 3(a) and 3(b) are side and sectional views showing a modified form of the

invention.

Figs. 4(a) and 4(b) are fragmentary side sectional views, representing a preferred embodiment of this invention, as will further be described hereinafter.

Figs. 5(a) and 5(b) represent a further embodiment in accordance with this invention.

Fig. 6 comprises Fig. 6(a) and 6(b) in accordance with this invention, showing a multiplicity of inlet channels, outlet channels and cross-axial pumps as will further be described in detail hereinafter. Fig. 6(a) is a sectional view taken through the mixer of Fig. 6(b), along the lines and arrows V-V; and

Figs. 7(a) and 7(b) show a further embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The current invention optimizes the mixing that takes place in a limited axial space along the extruder screw by providing multiple passes of plastic material drawn through a plurality of elongational mixing zones. This gives much greater latitude in design and achieves much better mixing results than heretofore suggested, as will further appear hereinafter.

In a mixer of this invention, the plastic material flow is shown schematically in Figs. 1(a) and 1(b) of the drawings. First inlet channel 21 is starved (partially empty) conveying material to first cross-axial pump 22. As the flow accelerates into cross-axial pump 22, an important improvement in mixing is created. Cross-axial pump 22 reorients the material in planar shear while pumping into the second channel inlet 23. Second channel inlet, also starved, conveys material to the inlet to subsequent cross-axial pump 24. Cross-axial pump 24 then functions as an output channel.

Fig. 2(b) shows the four flights 26 that tend to induce a certain amount of downstream flow in the various adjacent inlet channels.

First inlet channel 21 is starved (partially empty) conveying material to first cross-

axial pump 22. As the flow accelerates into cross-axial pump 22, an important improvement in mixing is created. Cross-axial pump 22 reorients the material in planar shear while pumping into second channel inlet 23. Second channel inlet 23, also starved, conveys material to the inlet to subsequent cross-axial pump 24 where subsequent acceleration and further mixing improvements take place. Subsequent cross-axial pump 24 further reorients the material in planar shear while pumping material to subsequent inlet channel 25. After subsequent mixing and pumping, material is delivered to final output channel 27. The cross-axial pumps 22 and 24 pump the mixture at an angle such as (a) in Fig. 2(a) and draw off the material from the inlet channels 21, 23, 25 until the supply is exhausted.

In the preferred embodiment shown in Fig. 4, the screw (which is driven in rotation by any suitable power source, not shown) has fifteen sections of inlet channels 11, cross-axially acting pumps and one outlet channel 12, and therefore provides exceptional mixing. Further flight 26 is shown to become a connected inlet and outlet flight that both guides material to first inlet channel 11 and from outlet channel 12.

Previous mixers have attempted to force material from one channel, over a barrier, and into a flight or channel such as in LeRoy U.S. Patent No. 3,486,192 and Dray U.S. Patent No. 3,788,612. Dray forced material from channel to flight in an uncontrolled manner, as shown in Dray U.S. Patent No. 3,788,612. By forcing, the flow fields were compressive rather than extensional.

The invention of Figs. 2 and 4 achieves a series of mixing stages, in extensional plastic material flow fields, in a short axial length compared to the length of the extruder screw. Extension of the plastic material is achieved by cross-axial drawing of the mixture from one channel directly to another channel at reduced pressure and preferably by operation in which the channels are in a partially empty mode. This latter mode may be achieved by starve feeding the inlet to the mixer, preferably by limiting the input amount by combined

use of a starve feeder (such a variable speed volumetric feeder) or, for example, by limiting the amount of material received by the mixer as a matter of screw design prior to the mixer.

It has heretofore been suggested, contrary to this invention, to provide possible means to reduce the amount of remixing. There is no mechanism suggested, to the best of my knowledge, that causes substantially all of the material to be remixed, as in this invention. Indeed, it has been indicated that additional feed rate to fill the end of the inlet channel would prevent remixing.

Fig. 5 of the drawings, like Figs. 2(a) and 2(b), shows disconnected inlet and outlet flights 8, 9 and also shows a multiplicity of inlet channels 1, 3, 5 and a multiplicity of outlet channels 7, with intervening cross-axial pumps 2, 4, 6 pumping in angular directions such as (a), (b), which are important features in accordance with this invention.

Figs. 6(a) and 6(b) show another embodiment of this invention comprising a multiplicity of these inlet and cross-axial pumping channels, working in combination with connected output flight 26 and where first cross-axial pump 22, second inlet channel 23, subsequent cross-axial pumps 24 and subsequent inlet channels 25 are bounded by a flight on two sides. This embodiment substantially prevents downstream flow from entering the mixer. The first inlet channel bears the number 21, the first cross-axial pump 22, the second inlet channel 23, the subsequent cross-axial pump 24, the subsequent inlet channel 25. The arrows (a) and (b) indicate cross-axial pumping, and arrow (c) designates downstream flow. The flight in the mixer section is identified as 26, while the final output channel is identified by the number 27. The input and output portions of flight 26 are identified as 28 and 29.

Figs. 3(a) and 3(b) show the use of a reverse screw flight 30 in a mixer otherwise similar to Figs. 2(a) and 2(b). In Figs. 3(a) and 3(b) the plastic material flow is from right to left, with the reverse flight urging the plastic material toward the right, into the outlet channels of the mixer for the purpose of control. It is preferred to limit the reverse effect to

avoid completely filling the mixer, because the mixer would then become compressive and lose the benefits of this invention.

Referring to Figs. 7(a) and 7(b), this embodiment includes a blister ring 31 to urge the plastic material toward the right, countercurrently. The blister ring 31 is a non-axial pumping ring which is designed as a narrow ring to control the mixer to be not quite filled, because it would then become compressive.

As an alternative, the channel depth could be reduced downstream of the mixer to decrease its pumping capacity, causing some plastic material to back up into the empty mixing channels.

It has been suggested that notches in the flight will permit material to flow through the flight into the inlet channel. Thus, the concept of notches permits material to flow either into one of the inlet channels or continued to be pumped out a discharge channel. This has serious drawbacks that the present invention overcomes.

A flight such as 26 in Fig. 6(b) has a small radial clearance from the extruder housing. A channel according to this invention has a large radial clearance from the extruder housing.

The flight 26 restricts flow for the purpose of promoting flow down and along the outlet channel. It is preferred for the flight 26 not to be a notched flight. A notched flight primarily promotes material into an inlet channel through the notches. When such flow exceeds the pumping capacity of the cross-axial pumps 22, 24, for example, the mixer flow will become undesirably compressive. A flight such as 26 in this invention includes variations in design sufficient to maintain elongational, non-compressive, flow in the mixer.

Although this invention has been described with reference to specific embodiments thereof, it will be appreciated that many variations may be made in the specific design of the extruder and its mixing section, including variations of the numbers and arrangements of inlet channels, cross-axial pumps, the number of inlet channels and cross-axial pumps, and

the number and arrangement of subsequent outlet channels. It will further be appreciated that the flight at the input and the exit ends of the mixing section can either be connected to or disconnected from the channels. Further, although it has been indicated as preferred to utilize a separate starve feeding mechanism, the invention is fully capable of operating with benefit and advantage in the absence of any such controlling mechanism. The dimensions of various channels may be specially designed to be similar or different from each other, where plural channels are utilized, and the dimensions of the first and subsequent cross-axial pumps can differ from each other. Although the channels may be oriented parallel to the screw axis, they may be angled as well. Further, some of the channels may be non-inlet channels and bounded by a flight on one side or more than one side. Many other variations may be made, as will readily become apparent to those skilled in the art.

What Is Claimed Is:

1. An extruder mixer for plastified material comprising a rotatable elongated screw and means for rotating said screw, said screw having a mixing section adapted to mix plastified materials, said mixing section having an inlet channel connected to a cross-axial pump constructed and arranged to feed a subsequent said channel, wherein said subsequent channel is connected to further feed said mixture to at least one subsequent cross-axial pump that is bounded by a flight on at least one side of said output channel to deliver the resulting plastic mixture.

2. The apparatus of Claim 1, wherein the cross-axial pumps are bounded by channels on more than one side.

3. The apparatus of Claim 1, wherein an upstream feeder is connected to cause and to control input feed of mixable materials.

4. The apparatus of Claim 1, where a screw channel is provided at the input of said mixer to control the flow rate mixer input.

5. The apparatus of Claim 1, where an output flight is connected to a downstream flight of said mixer section.

6. The apparatus of Claim 1, where an output flight is connected to a channel of said extruder mixing section.

7. The apparatus of Claim 1, wherein the dimensions of said first and subsequent

channels are substantially the same as each other.

8. The apparatus of Claim 1, wherein said extruder screw is substantially vertically oriented.

9. The apparatus of Claim 1, wherein the dimensions of said first and subsequent channels are different from each other.

10. The apparatus of Claim 1, wherein the dimensions of said first and subsequent cross-axial pumps are the same.

11. The apparatus of Claim 1, wherein the dimensions of said first and subsequent cross-axial pumps are different from each other.

12. The apparatus of Claim 1, wherein said channels are oriented substantially parallel to the screw axis.

13. The apparatus of Claim 1, wherein said channels are oriented at an angle to the screw axis.

14. The apparatus of Claim 1, wherein at least some of the channels are unconnected to said inlet channel and are bounded by a flight on one side.

15. The apparatus of Claim 14, wherein at least some of said non-inlet channels are bounded by a flight on two sides.

16. The apparatus of Claim 1, wherein said mixer is not starve fed.

17. The apparatus of Claim 1, where resistance devices are provided on said screw to force said plastic material into said outlet channels.

18. The apparatus of Claim 1, wherein there are multiple inlet channels.

19. The apparatus of Claim 1, wherein there are multiple connected inlet flights.

20. The apparatus of Claim 1, wherein there are multiple connected outlet flights.

21. In a method of mixing plastic or plastifiable materials in an extruder comprising a rotatable extruder screw having a mixing section comprising a plurality of inlet and outlet channels for said materials, the steps which comprise:

(a) drawing said materials into an inlet channel,

(b) cross-axially pumping said material from said inlet channel to at least one subsequent said inlet channel, and

(c) cross-axially pumping said material.

22. The method of Claim 21, comprising the further step of cross-axially pumping said material into an outlet channel.

23. The method of Claim 21 comprising the further step of controlling upstream feed of input of said material to said extruder.

24. The method of Claim 23, wherein said input is fed through a screw channel, and wherein said step of controlling comprises constraining the feed rate of said screw channel.

25. The method of Claim 21 comprising the further step of controlling the rate of material output from said outlet channel.

26. The method of Claim 23, wherein an output flight is connected to a channel of said extruder, and wherein said step of controlling comprises limiting the rate of rotation of said output flight.

27. The method of Claim 21, comprising the step of starve feeding said extruder.

28. The method of Claim 21 comprising the step of applying resistance to output material flow to force said plastic material into said outlet channel.

29. The method of Claim 21 comprising the step of introducing said plastifiable material separately into a plurality of separate inlet channels.

30. The method of Claim 21 comprising the step of concurrently feeding said plastifiable material into a multiplicity of individual channels.

31. The method of Claim 21 including the further step of connecting a plurality of said channels together for concurrent flow of said material therein.

32. The method of Claim 21 comprising the step of removing said mixed material

concurrently through a plurality of multiple outlet flights.

33. The method of Claim 21 comprising the further step of maintaining said plastifiable material in a melted state within said mixing section.

ABSTRACT OF THE DISCLOSURE

An extruder mixer and method for mixing plastic materials utilizes an elongated screw having an inlet channel connected to a first cross-axial pump that feeds, at an angle to the screw axis, a subsequent channel, wherein the subsequent channel becomes a further inlet channel connected to at least one subsequent cross-axial pump, and wherein the cross-axial pump is bounded by a flight on at least one side.

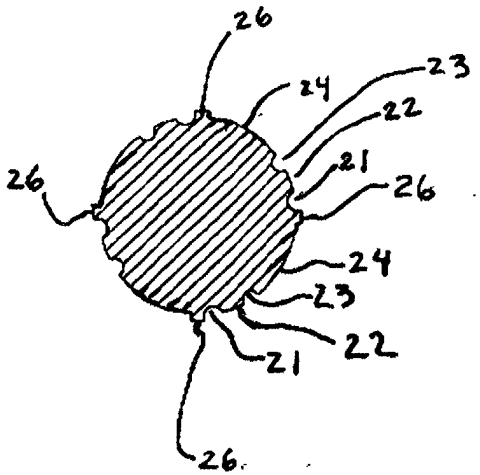

FIG. 1 (b)

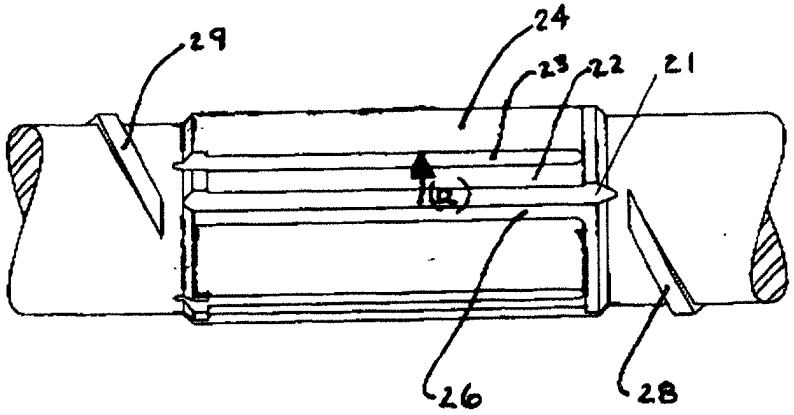

FIG. 1 (a)

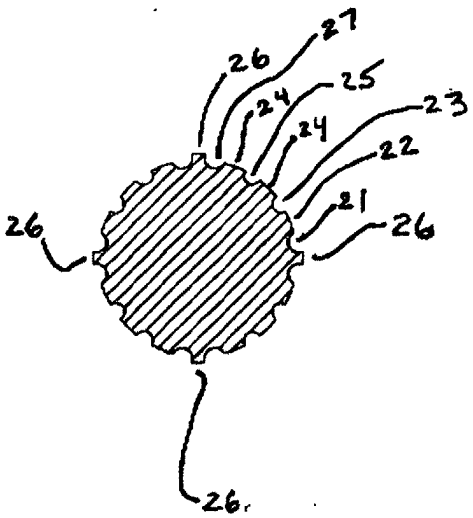

FIG. 2(b)

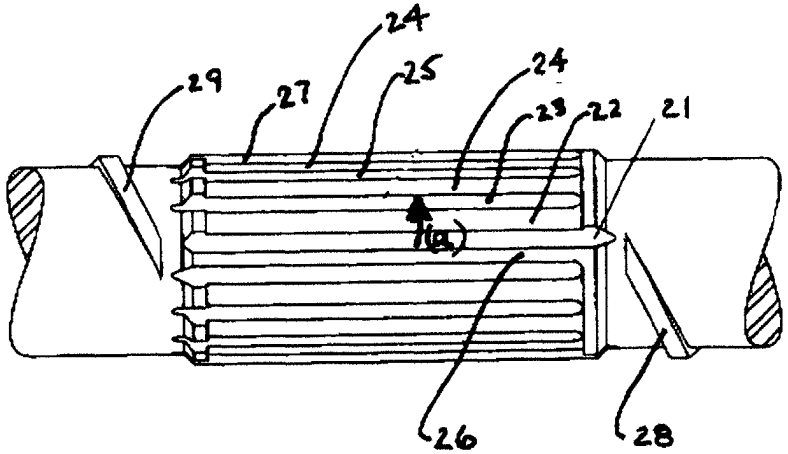

FIG. 2(a)

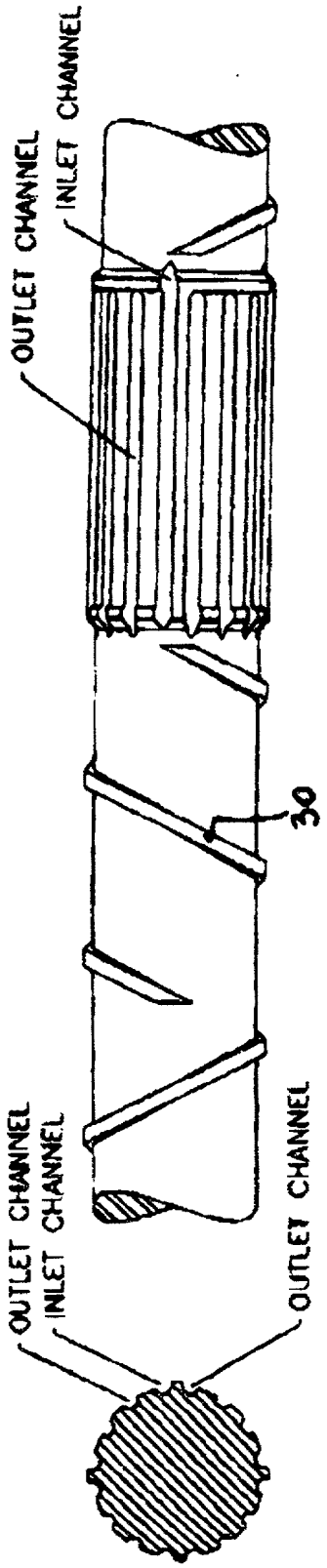
OUTLET CHANNEL
INLET CHANNEL
30
OUTLET CHANNEL
INLET CHANNEL
OUTLET CHANNEL

FIG. 3(a)

FIG. 3(b)

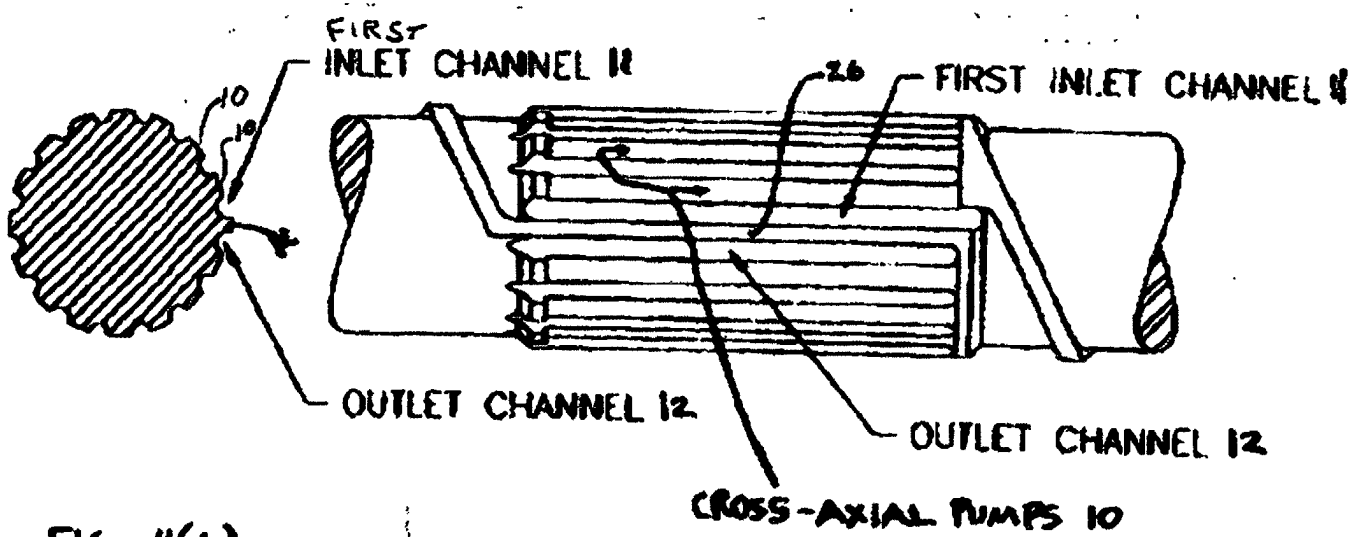

FIG. 4(b)

FIG. 4(a)

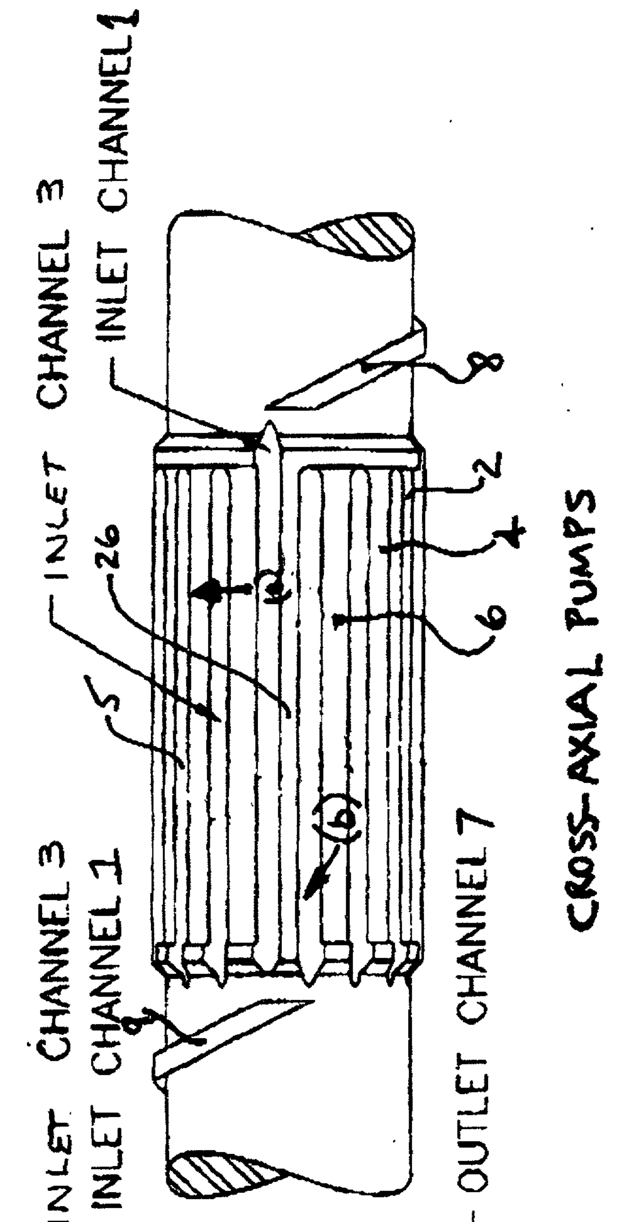
INLET CHANNEL 3
INLET CHANNEL 1
INLET CHANNEL 3
INLET CHANNEL 1
OUTLET CHANNEL 7
26
5
8
2
4
6
(b)
CROSS-AXIAL PUMPS

FIG. 5(a)

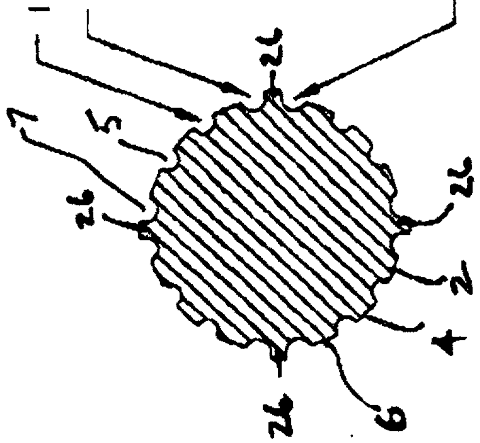
7
5
26
26
26
26
2
4
6

FIG. 5(b)

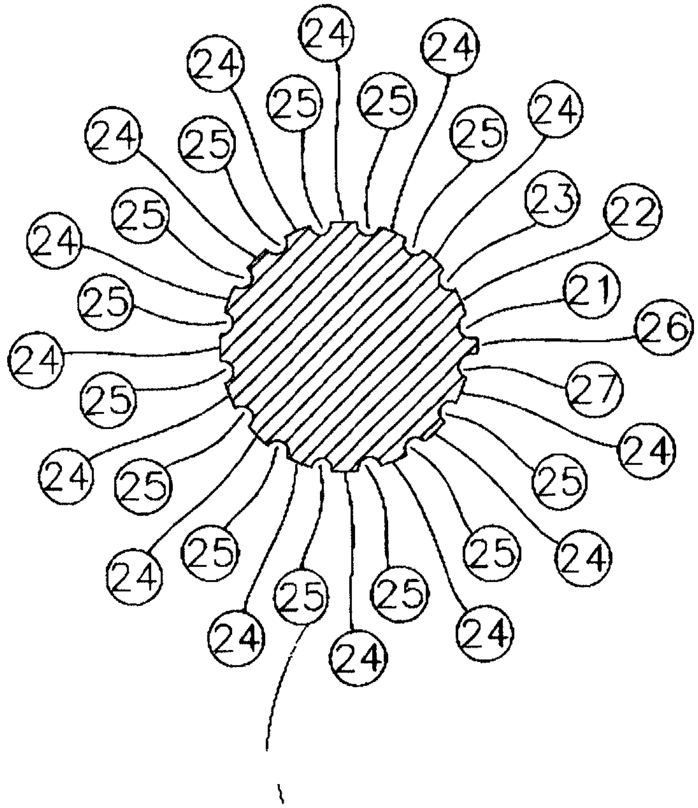

FIG. 6(a)

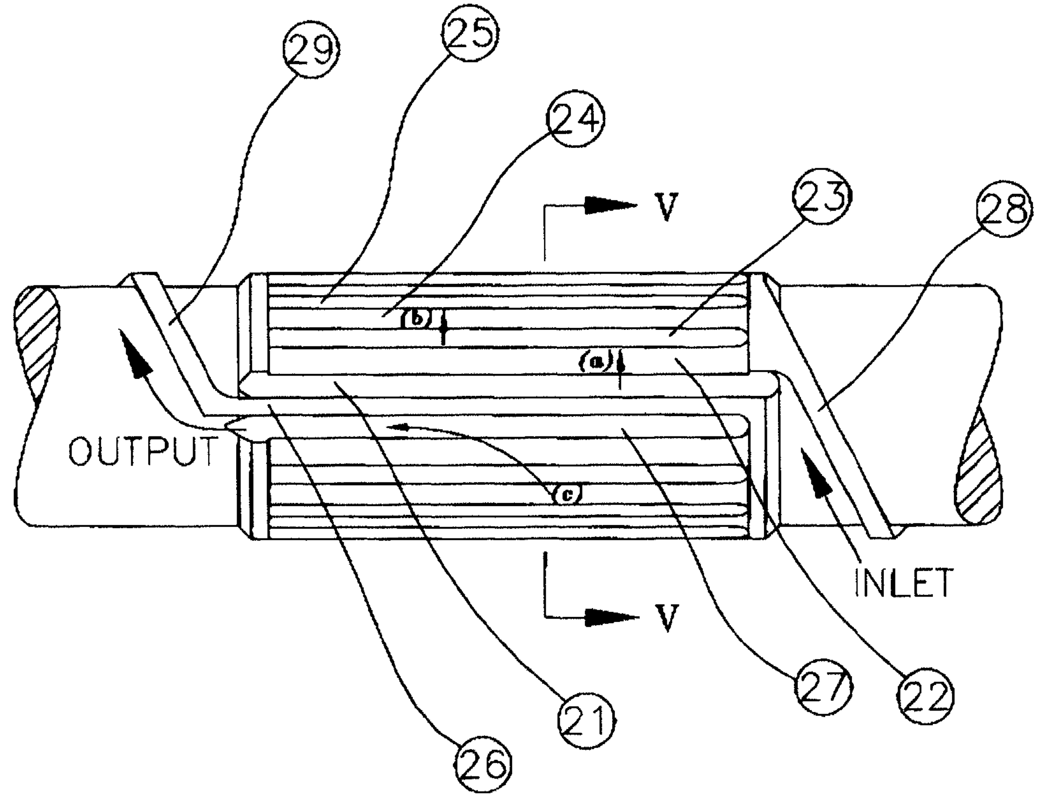

FIG. 6(b)

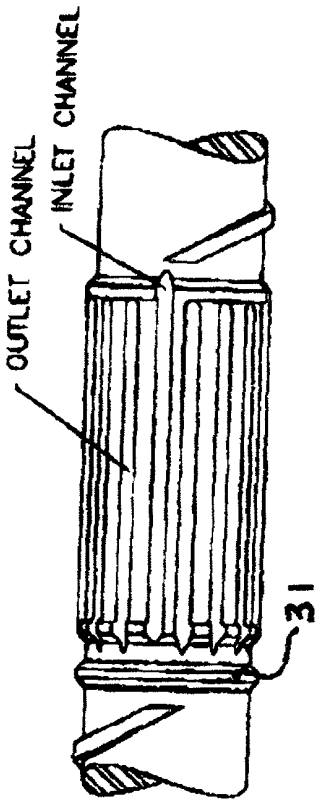
OUTLET CHANNEL
INLET CHANNEL
31

Fig. 7(a)

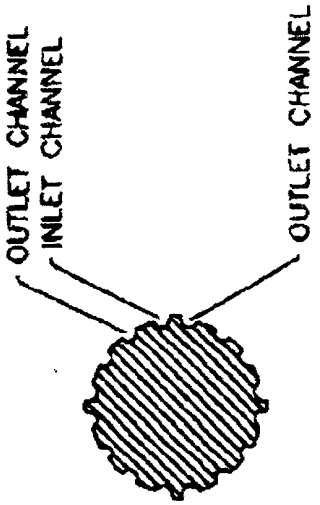
OUTLET CHANNEL
INLET CHANNEL
OUTLET CHANNEL

Fig. 7(b)